Year: 1996

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DOI: https://doi.org/10.1515/bmte.1996.41.s1.206

Originally published at:
Ladd, Mark E; Erhart, Peter; Göhde, Susanne C; Debatin, Jörg F; McKinnon, Graeme C (1996). Guidewire Antennas for MRI-Guided Vascular Interventions. Biomedizinische Technik. Biomedical engineering, 41(s1):206-207.
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Guidewire Antennas for MRI-Guided Vascular Interventions

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Introduction

Because of its excellent soft tissue contrast, ability to image in an arbitrary plane, and lack of ionizing radiation, great interest has been shown in using MRI to guide vascular interventions. Before a catheter can be safely introduced, a guidewire needs to be placed. Unlike conventional X-ray fluoroscopy, however, the ability to quickly and reliably visualize thin objects like guidewires has proven to be difficult. One solution is the use of active receive antennas built into the guidewire tip (1).

A number of antenna configurations are possible, including simple loop, solenoid, center return, etc. (2). In order to understand and optimize these antennas, a series of theoretical simulations and experimental measurements were performed. In addition, the effect of adding a passive signal source (e.g. water) internal to the guidewire was explored.

Methods

Biot-Savart modelling was used to calculate the magnetic field patterns of the following antenna types: single loop, crossed loop, 4-wire center return, and solenoid. From these field patterns, sagittal-like images with a slice thickness of 5 mm were simulated with the coils both parallel and perpendicular to the main magnetic field, B_0, of the MR imager. The in-plane resolution was 0.1 mm in both directions.

Prototype guidewires were constructed by Schneider Europe AG. Each guidewire was constructed with a coil approximately 60 mm long and 0.6 mm in diameter. After enclosing the guidewire in a Teflon sheath, the final outside diameter was 0.75 mm, small enough to fit into the lumen of a 5 French catheter.

Water doped with Gd-DTPA (Schering AG) was injected into the prototype guidewires as an internal, passive signal source.

Results

Fig. 1 shows a simulated image of a single loop guidewire with no signal source in the interior of the coil. The coil is parallel to B_0. Fig. 2 shows the same coil with an internal signal source.

Fig. 3 shows the profiles of image intensity from left to right for both cases. The profiles show that the internal source not only increases the available signal, it also narrows the apparent line width of the guidewire.

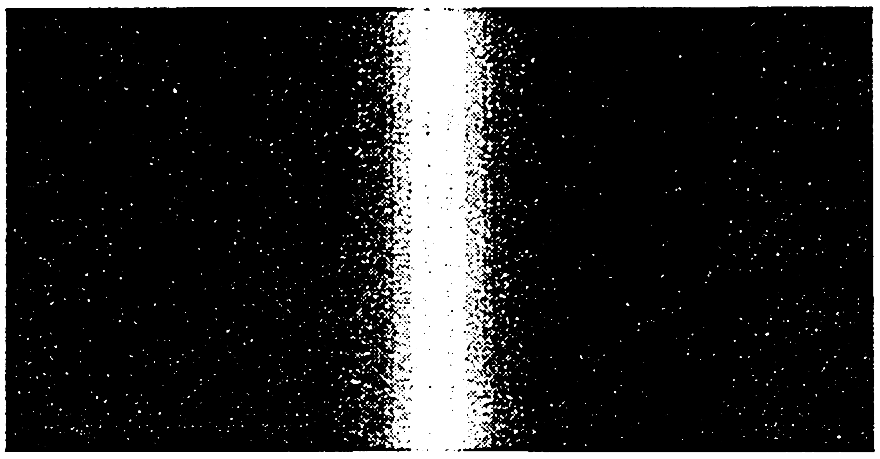

Fig. 1. Simulated image of single loop guidewire without *internal signal source.*

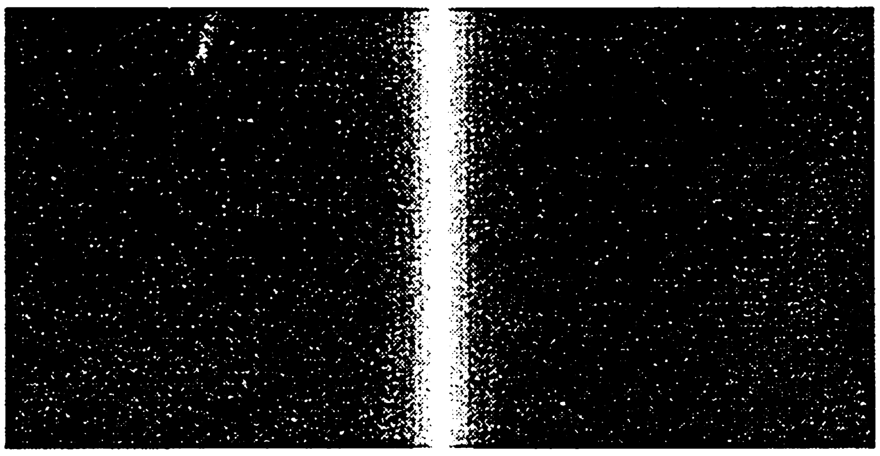

Fig. 2. Simulated image of single loop guidewire with *internal signal source.*

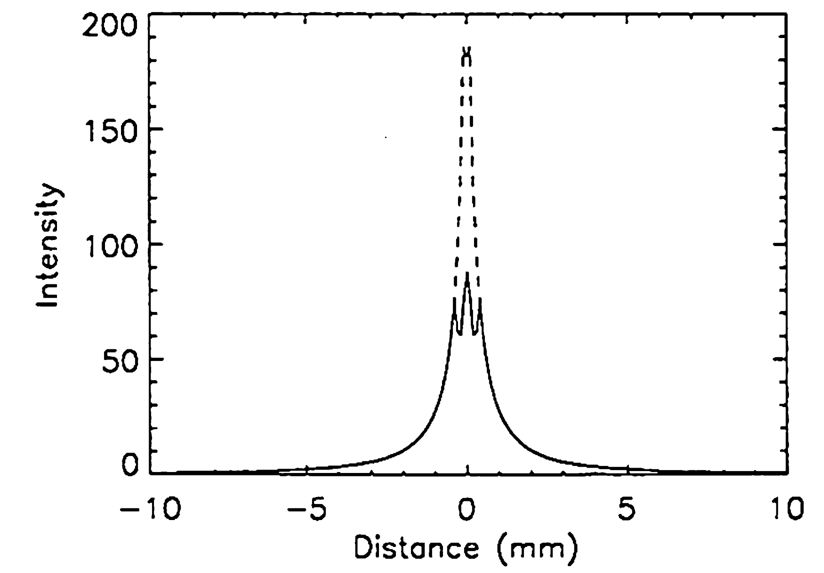

Fig. 3. Profiles of image intensity across the above images. Solid line = without *internal source, dashed line* = with *internal source.*

This is also desirable, since it provides better localization. If the internal source is a substance with a short relaxation time T_1, then a third benefit is the ability to scan with fast imaging sequences (short TR's).

Fig. 4 shows a magnified, experimental image of the single loop prototype taken with the coil parallel to B_0. Water/Gd-DTPA was injected into the interior of the coil. The 6 cm tip of the guidewire is depicted quite well. Sequence parameters were TR 300 ms, TE 2.3 ms (fractional), flip angle 60°, FOV 20 cm, matrix 512x512, 1 NEX.

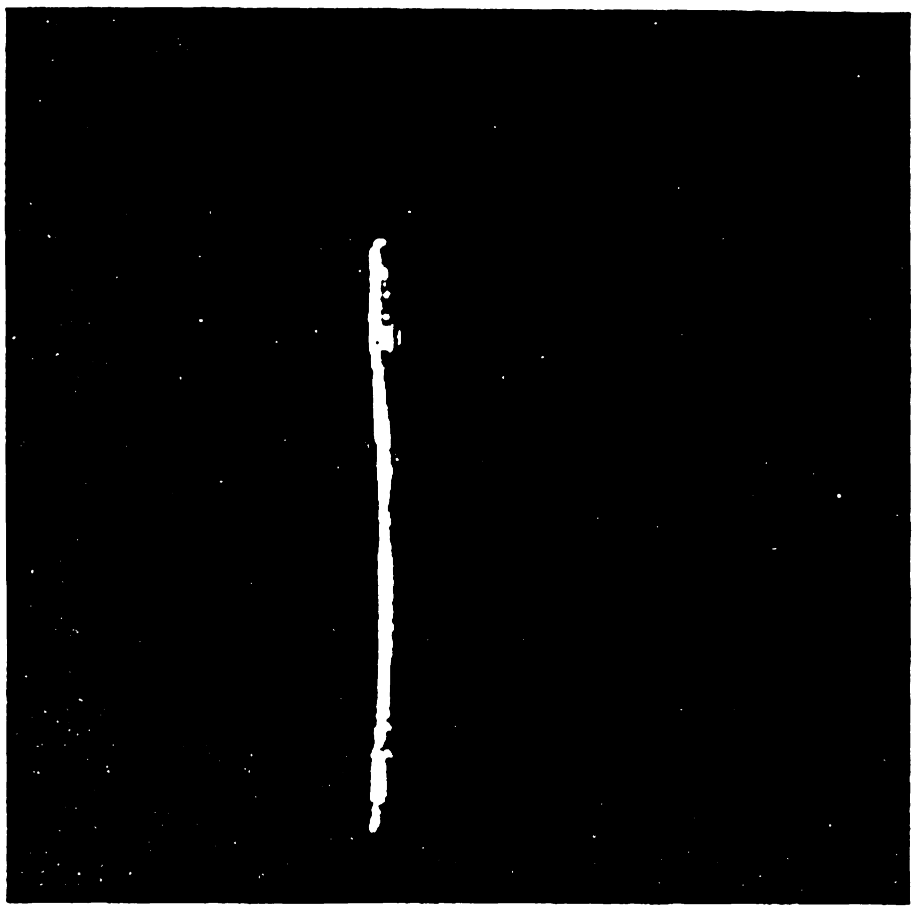

Fig. 4. Experimental image of single loop prototype guidewire parallel to B_0.

Conclusion

The selection of the appropriate guidewire coil depends on a combination of factors. The single loop, crossed loop, and center return all perform better parallel to B_0. The solenoid performs best orthogonal to B_0. Thus, depending on where the intervention is to be performed, one might choose one over the other.

A second factor is ease of mechanical construction. The single loop and solenoid are both easy to construct. The crossed loop and center return are more difficult because four long wires need to be kept straight and equidistant. This proved problematic in the prototypes.

The most deciding factor is the addition of a passive signal source in the highly sensitive area near the center of the coil. This increases the SNR, reduces the line with, and with Gd-DTPA induced T1 shortening, permits the use of fast imaging.

Acknowledgments

This work was funded by General Electrical Medical Systems, Milwaukee, Wisconsin, and the Swiss National Science Foundation, Grant Nr. 32-43284.95.

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